



US009368402B2

(12) **United States Patent**  
**Huang et al.**

(10) **Patent No.:** **US 9,368,402 B2**  
(45) **Date of Patent:** **Jun. 14, 2016**

(54) **CONDUCTIVE LINE SYSTEM AND PROCESS**

(2013.01); **H01L 23/53238** (2013.01); **H01L 24/03** (2013.01); **H01L 23/53223** (2013.01);

(Continued)

(71) Applicant: **Taiwan Semiconductor Manufacturing Company, Ltd.**, Hsin-Chu (TW)

(72) Inventors: **Yu Yi Huang**, Yongjing Township (TW);  
**Hung-Jui Kuo**, Hsin-Chu (TW);  
**Chung-Shi Liu**, Hsin-Chu (TW)

(58) **Field of Classification Search**

None

See application file for complete search history.

(73) Assignee: **Taiwan Semiconductor Manufacturing Company, Ltd.**, Hsin-Chu (TW)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,072,527 A 2/1978 Fan  
4,212,935 A 7/1980 Canavello et al.

(Continued)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **14/833,760**

EP 1500977 A1 1/2005  
JP 2006145788 A 6/2006

(22) Filed: **Aug. 24, 2015**

(Continued)

(65) **Prior Publication Data**

US 2015/0364369 A1 Dec. 17, 2015

OTHER PUBLICATIONS

Hoo, Ng Wah et al., "The Effect of UPW Quality on Photolithography Defect," Proc. SPIE 7520, Lithography Asia 2009, Dec. 14, 2009, 7 pages, vol. 7520, SPIE, Taipei, Taiwan.

(Continued)

**Related U.S. Application Data**

(62) Division of application No. 13/929,641, filed on Jun. 27, 2013, now Pat. No. 9,117,881.

(60) Provisional application No. 61/789,593, filed on Mar. 15, 2013.

*Primary Examiner* — Sonya D McCall Shepard

(74) *Attorney, Agent, or Firm* — Slater Matsil, LLP

(51) **Int. Cl.**

**H01L 21/473** (2006.01)

**H01L 21/768** (2006.01)

(Continued)

(57)

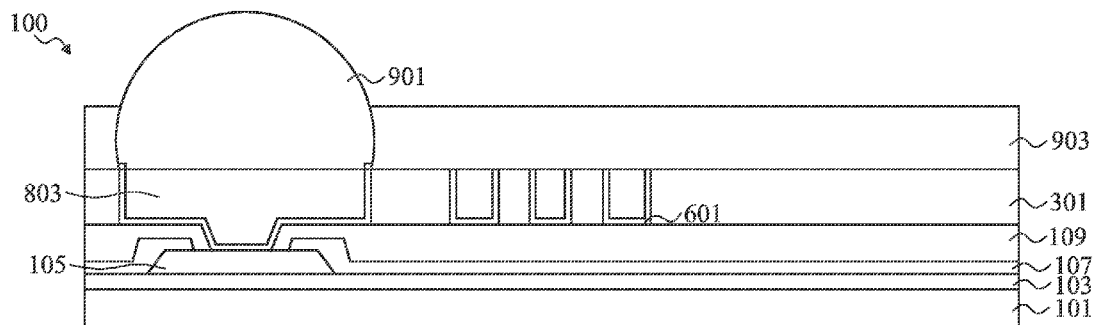
**ABSTRACT**

A system and method for providing a conductive line is provided. In an embodiment the conductive line is formed by forming two passivation layers, wherein each passivation layer is independently patterned. Once formed, a seed layer is deposited into the two passivation layers, and a conductive material is deposited to fill and overfill the patterns within the two passivation layers. A planarization process such as a chemical mechanical polish may then be utilized in order to remove excess conductive material and form the conductive lines within the two passivation layers.

(52) **U.S. Cl.**

CPC ..... **H01L 21/76879** (2013.01); **H01L 21/0274** (2013.01); **H01L 21/02118** (2013.01); **H01L 21/2885** (2013.01); **H01L 21/7684** (2013.01); **H01L 21/76802** (2013.01); **H01L 21/76807** (2013.01); **H01L 21/76816** (2013.01); **H01L 21/76873** (2013.01); **H01L 23/293** (2013.01); **H01L 23/3192** (2013.01); **H01L 23/5329**

**20 Claims, 7 Drawing Sheets**



- (51) **Int. Cl.**
- H01L 23/31* (2006.01) 7,393,624 B2 7/2008 Allen et al.
- H01L 23/29* (2006.01) 7,432,035 B2 10/2008 Maeda et al.
- H01L 23/00* (2006.01) 7,432,042 B2 10/2008 Chang et al.
- H01L 21/02* (2006.01) 7,460,206 B2 12/2008 Weissenrieder et al.
- H01L 21/027* (2006.01) 7,470,503 B1 12/2008 Brandl
- H01L 21/288* (2006.01) 7,582,398 B2 9/2009 Iftime et al.
- H01L 23/532* (2006.01) 7,585,612 B2 9/2009 Thackeray et al.
- (52) **U.S. Cl.**
- CPC ..... *H01L 23/53252* (2013.01); *H01L 24/05* (2013.01); *H01L 24/11* (2013.01); *H01L 24/13* (2013.01); *H01L 2221/1031* (2013.01); *H01L 2224/0345* (2013.01); *H01L 2224/0381* (2013.01); *H01L 2224/03452* (2013.01); *H01L 2224/03462* (2013.01); *H01L 2224/03464* (2013.01); *H01L 2224/03616* (2013.01); *H01L 2224/0401* (2013.01); *H01L 2224/05147* (2013.01); *H01L 2224/05166* (2013.01); *H01L 2224/05624* (2013.01); *H01L 2224/05644* (2013.01); *H01L 2224/05647* (2013.01); *H01L 2224/1132* (2013.01); *H01L 2224/1144* (2013.01); *H01L 2224/1145* (2013.01); *H01L 2224/11334* (2013.01); *H01L 2224/11462* (2013.01); *H01L 2224/11849* (2013.01); *H01L 2224/13022* (2013.01); *H01L 2224/13111* (2013.01); *H01L 2224/13139* (2013.01); *H01L 2224/13147* (2013.01); *H01L 2924/12042* (2013.01)
- (56) **References Cited**
- U.S. PATENT DOCUMENTS
- 4,268,601 A 5/1981 Namiki et al.
- 4,289,845 A 9/1981 Bowden et al.
- 4,346,164 A 8/1982 Tabarelli et al.
- 4,491,628 A 1/1985 Ito et al.
- 4,663,275 A 5/1987 West et al.
- 4,777,119 A 10/1988 Brault et al.
- 4,939,070 A 7/1990 Brunsvold et al.
- 5,002,850 A 3/1991 Shinozaki et al.
- 5,268,260 A 12/1993 Bantu et al.
- 5,288,588 A 2/1994 Yukawa et al.
- 5,738,975 A 4/1998 Nakano et al.
- 5,750,312 A 5/1998 Chandross et al.
- 5,766,824 A 6/1998 Batchelder et al.
- 5,856,065 A 1/1999 Hagen
- 5,863,710 A 1/1999 Wakiya et al.
- 5,886,102 A 3/1999 Sinta et al.
- 5,889,141 A 3/1999 Marrocco, III et al.
- 6,008,265 A 12/1999 Vallee et al.
- 6,147,249 A 11/2000 Watanabe et al.
- 6,187,504 B1 2/2001 Suwa et al.
- 6,306,554 B1 10/2001 Barclay et al.
- 6,627,377 B1 9/2003 Itatani et al.
- 6,674,162 B2 1/2004 Takao
- 6,787,289 B2 9/2004 Yamada et al.
- 6,788,477 B2 9/2004 Lin
- 6,790,579 B1 9/2004 Goodall et al.
- 6,835,527 B2 12/2004 Takata et al.
- 6,852,473 B2 2/2005 Roberts et al.
- 6,872,503 B2 3/2005 Wheland et al.
- 6,875,554 B2 4/2005 Hatanaka et al.
- 6,936,400 B2 8/2005 Takasu et al.
- 6,952,253 B2 10/2005 Lof et al.
- 6,991,888 B2 1/2006 Padmanaban et al.
- 7,195,860 B2 3/2007 Endo et al.
- 7,235,348 B2 6/2007 Ho et al.
- 7,264,918 B2 9/2007 Endo et al.
- 7,312,014 B2 12/2007 Maesawa et al.
- 7,320,855 B2 1/2008 Huang et al.
- 7,344,970 B2 3/2008 Forman et al.
- 7,362,412 B2 4/2008 Holmes et al.
- 2001/0044070 A1 11/2001 Uetani et al.
- 2002/0015826 A1 2/2002 Desmarteau et al.
- 2002/0051933 A1 5/2002 Kodama et al.
- 2002/0068237 A1 6/2002 Imai
- 2002/0096757 A1 7/2002 Takao et al.
- 2003/0022097 A1 1/2003 Malik et al.
- 2003/0073027 A1 4/2003 Namiki et al.
- 2003/0079764 A1 5/2003 Hirose et al.
- 2003/0087179 A1 5/2003 Iwasaki
- 2003/0175624 A1 9/2003 Nozaki et al.
- 2004/0038520 A1 2/2004 Seto et al.
- 2004/0084150 A1 5/2004 George et al.
- 2004/0096780 A1 5/2004 Nozaki et al.
- 2004/0161698 A1 8/2004 Kanagasabapathy et al.
- 2004/0180299 A1 9/2004 Rolland et al.
- 2005/0134817 A1 6/2005 Nakamura
- 2005/0145803 A1 7/2005 Hakey et al.
- 2005/0145821 A1 7/2005 French et al.
- 2005/0225737 A1 10/2005 Weissenrieder et al.
- 2005/0266354 A1 12/2005 Li et al.
- 2005/0287466 A1 12/2005 Miyamoto et al.
- 2006/0008736 A1 1/2006 Kanda et al.
- 2006/0105267 A1 5/2006 Khojasteh et al.
- 2006/0141400 A1 6/2006 Hirayama et al.
- 2006/0204890 A1 9/2006 Kodama
- 2006/0246373 A1 11/2006 Wang
- 2006/0257781 A1 11/2006 Benoit et al.
- 2006/0257785 A1 11/2006 Johnson
- 2007/0031755 A1 2/2007 Hirayama et al.
- 2007/0207406 A1 9/2007 Guerrero et al.
- 2008/0113300 A2 5/2008 Choi et al.
- 2008/0149135 A1 6/2008 Cho et al.
- 2008/0160729 A1 7/2008 Krueger et al.
- 2008/0187860 A1 8/2008 Tsubaki et al.
- 2008/0241778 A1 10/2008 Kulp
- 2009/0042147 A1 2/2009 Tsubaki
- 2009/0305163 A1 12/2009 Iwashita et al.
- 2009/0311624 A1 12/2009 Horiguchi et al.
- 2010/0040971 A1 2/2010 Tarutani et al.
- 2010/0239984 A1 9/2010 Tsubaki
- 2011/0020755 A1 1/2011 Tsubaki
- 2011/0097670 A1 4/2011 Wang et al.
- 2011/0250543 A1 10/2011 Tsubaki
- 2011/0263136 A1 10/2011 Kim et al.

(56)

**References Cited**

## U.S. PATENT DOCUMENTS

2012/0052687	A1	3/2012	Raghavan et al.
2012/0171616	A1	7/2012	Thackeray et al.
2012/0238106	A1	9/2012	Chuang
2012/0282553	A1	11/2012	Kimura et al.
2012/0308741	A1	12/2012	Kim et al.
2012/0308939	A1	12/2012	Kudo et al.
2014/0011133	A1	1/2014	Liu et al.

## FOREIGN PATENT DOCUMENTS

TW	1336819	B	2/2011
TW	1341961	B	5/2011
TW	1343513	B	6/2011
WO	2005088397	A2	9/2005
WO	2006054432	A1	5/2006

## OTHER PUBLICATIONS

Kitano, Junichi et al., "Resist pattern collapse prevention for the sub-90nm node," Microlithography World, May 2004, pp. 18-24, PennWell Publishing Corp.

Kunz, Roderick R., Kunz SPIE Short Course, 21 pages, MIT Lincoln Library, 2002, publisher unknown.

Lau, Aldrich N. K. et al., "New Thermal Cross-Linkers Based on Triazene: Cross-Linking of Fluorinated Polyimides and Aromatic Polymers," *Macromolecules*, 1992, pp. 7294-7299, vol. 25.

Reiser, Arnost, "Photoreactive Polymers: The Science and Technology of Resists," Feb. 1989, 409 pages, Wiley-Interscience, New York.

Robertson, Stewart et al., "Physical Resist Simulation for a Negative Tone Development Process," 2010 International Symposium on Lithography Extension, Oct. 20-22, 2010, 19 pages.

Sekiguchi, Atsushi et al., "Analysis of Deprotection Reaction in Chemically Amplified Resists Using an Fourier Transform Infrared Spectrometer with an Exposure Tool," *Japan J. Appl. Phys.*, Mar. 2000, pp. 1392-1398, vol. 39, Part 1, No. 3A.

Switkes, M. et al., "Extending optics to 50 nm and beyond with immersion lithography," *Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures*, Nov./Dec. 2003, vol. 21, No. 6., pp. 2794-2799.

Tarutani, Shinji et al., "Process parameter influence to negative tone development process for double patterning," *Proc. SPIE 7639, Advances in Resist Materials and Processing Technology XXVII*, Mar. 29, 2010, 13 pages, vol. 7639.

Tsvetanova, D. et al., "Degradation of 248 nm Deep UV Photoresist by Ion Implantation," *Journal of the Electromechanical Society*, Jun. 10, 2011, 10 pages, vol. 158, Issue 8, The Electromechanical Society.

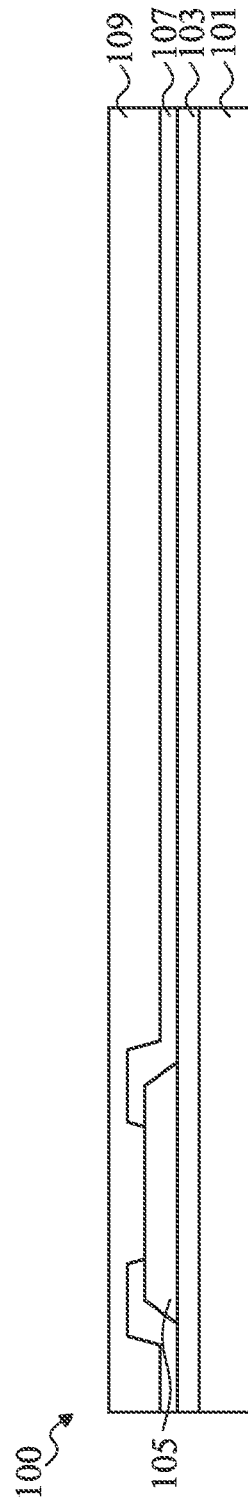


Fig. 1

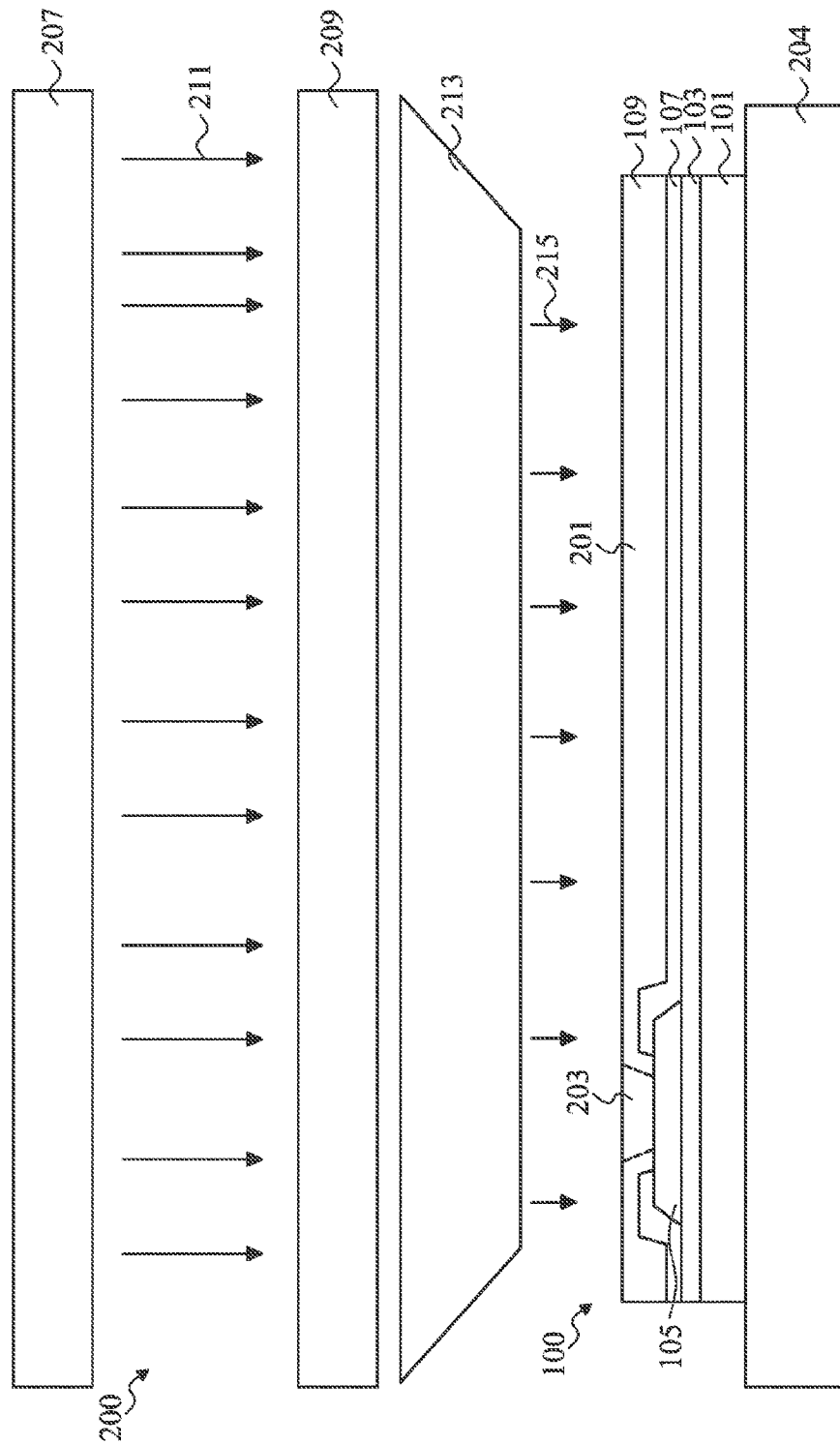


Fig. 2A

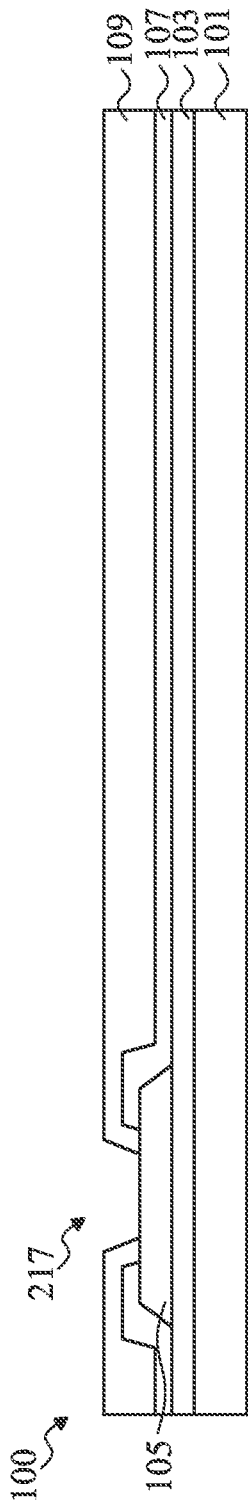


Fig. 2B

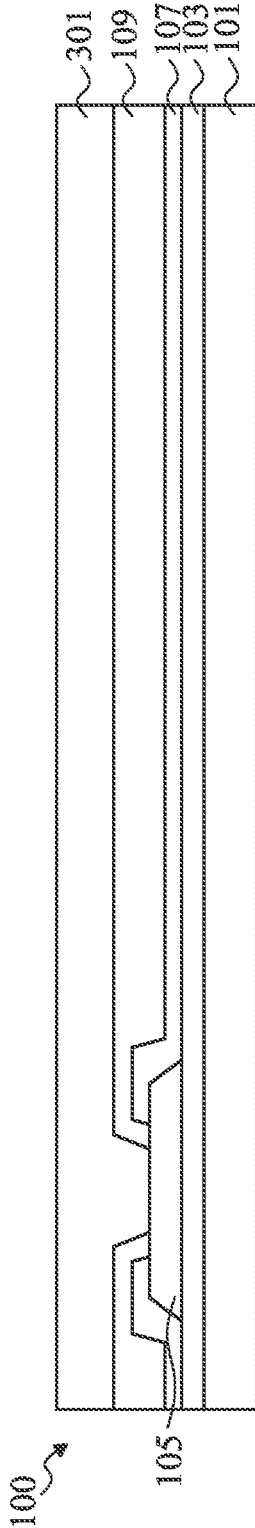


Fig. 3

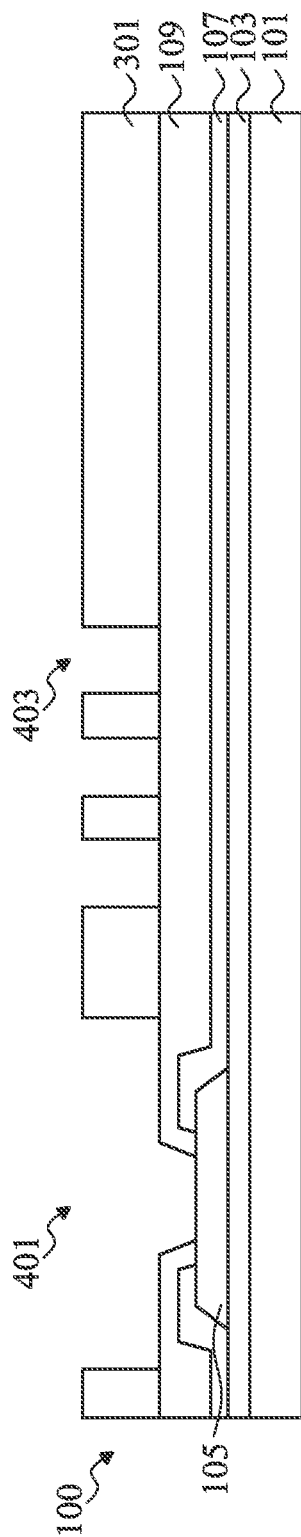


Fig. 4

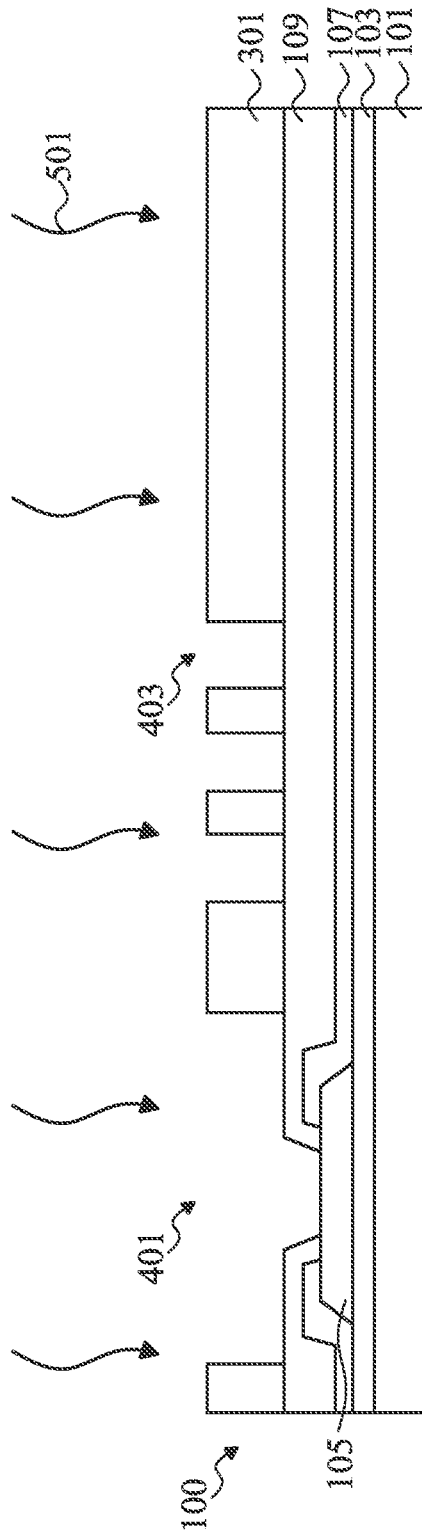


Fig. 5

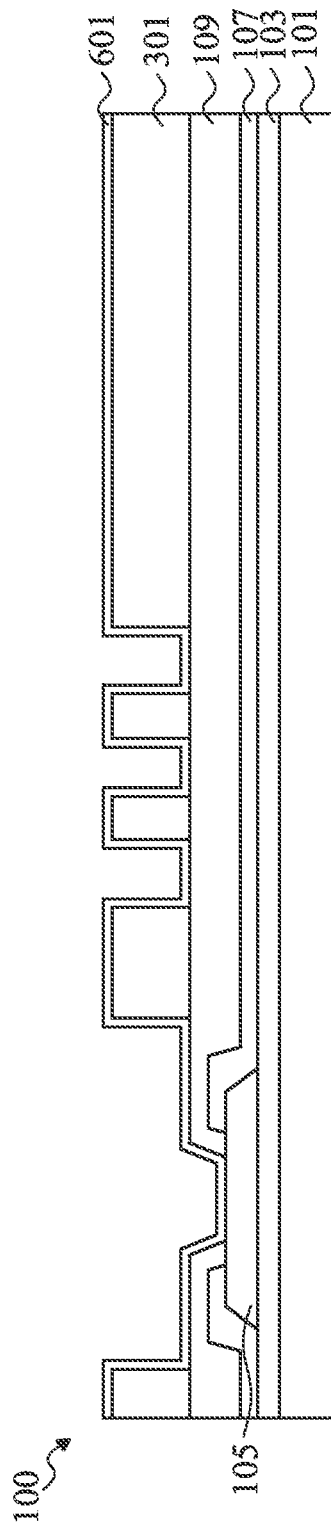


Fig. 6

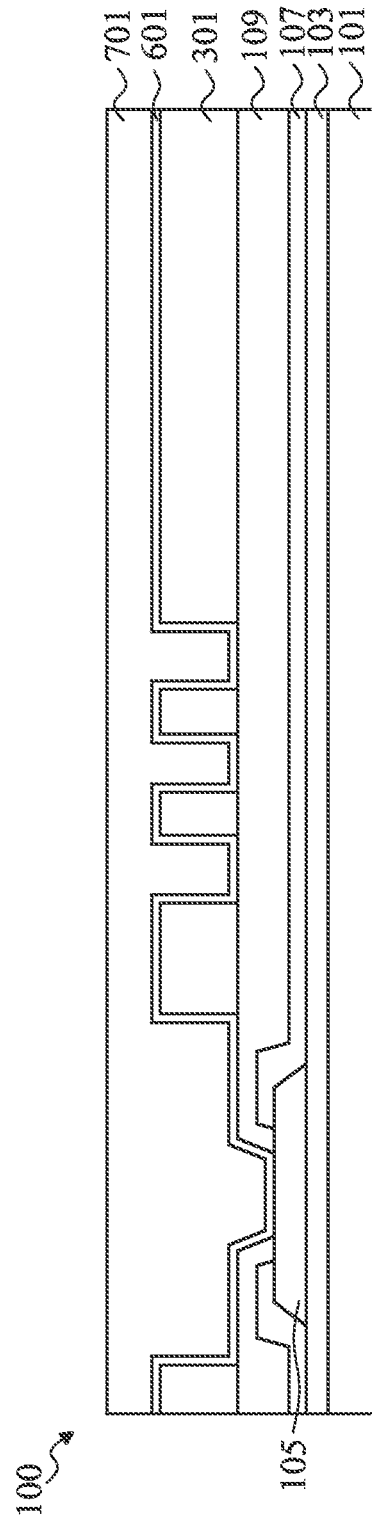


Fig. 7



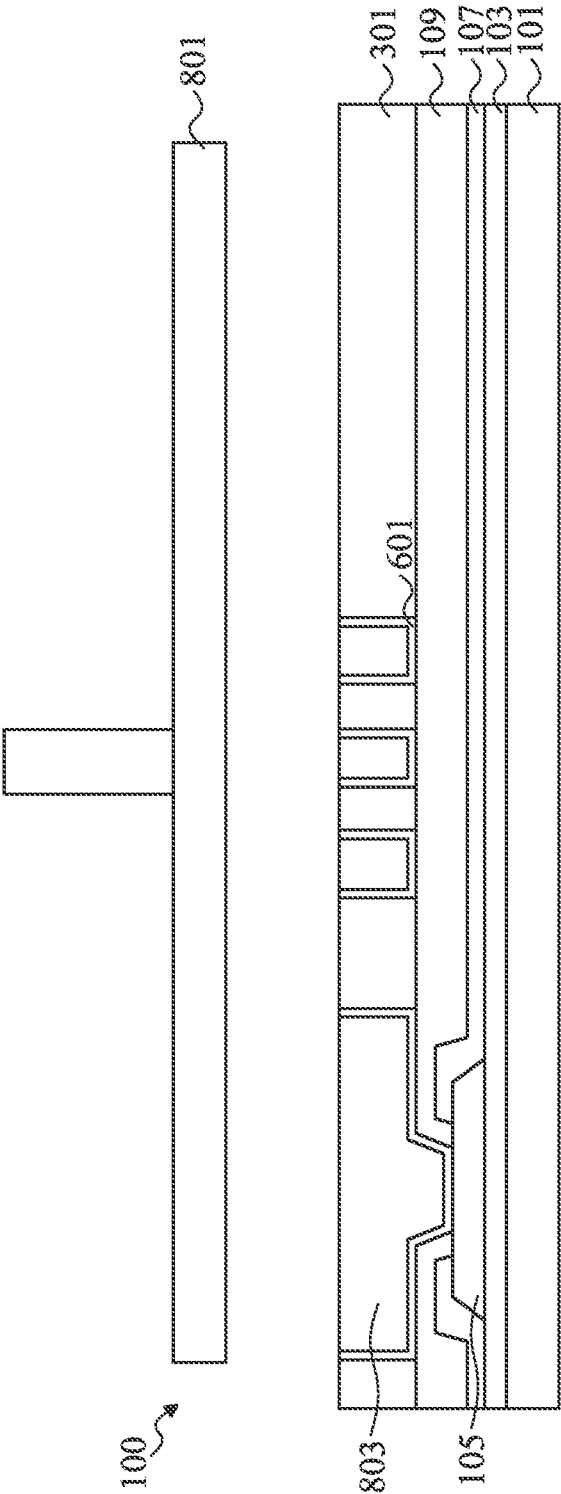


Fig. 8

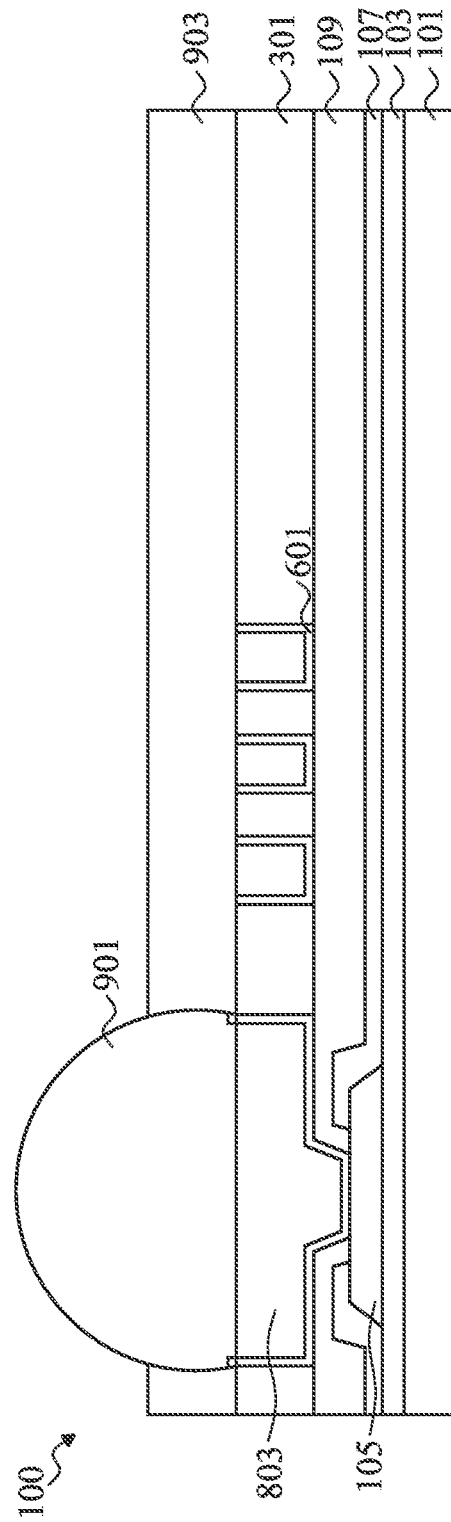


Fig. 9

## CONDUCTIVE LINE SYSTEM AND PROCESS

This application is a division of and claims the benefit of U.S. patent application Ser. No. 13/929,641, filed on Jun. 27, 2013 and entitled "Conductive Line System and Process," which claims priority to U.S. Provisional Application No. 61/789,593, filed on Mar. 15, 2013, and entitled "Conductive Line System and Process," which applications are incorporated herein by reference.

## BACKGROUND

Generally, active devices and passive devices are formed on and in a semiconductor substrate. Once formed, these active devices and passive devices may be connected to each other and to external devices using a series of conductive and insulative layers. These layers may help to interconnect the various active devices and passive devices as well as provide an electrical connection to external devices through, for example, a contact pad. To provide additional flexibility to designs, a post-passivation interconnect may be utilized to position external contacts where desired after the contact pad has been formed and after passivation layers have been formed over the contact pad.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the embodiments, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates a cross-sectional view of a substrate with a second passivation layer over a contact pad in accordance with an embodiment;

FIGS. 2A-2B illustrate a patterning and development of the second passivation layer in accordance with an embodiment;

FIG. 3 illustrates a placement of a third passivation layer in accordance with an embodiment;

FIG. 4 illustrates a patterning and development of the third passivation layer in accordance with an embodiment;

FIG. 5 illustrates a curing process in accordance with an embodiment;

FIG. 6 illustrates a formation of a seed layer in accordance with an embodiment;

FIG. 7 illustrates a formation of a conductive material in accordance with an embodiment;

FIG. 8 illustrates a planarization process in accordance with an embodiment; and

FIG. 9 illustrates an external contact and buffer layer in accordance with an embodiment.

Corresponding numerals and symbols in the different figures generally refer to corresponding parts unless otherwise indicated. The figures are drawn to clearly illustrate the relevant aspects of the embodiments and are not necessarily drawn to scale

## DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The making and using of the present embodiments are discussed in detail below. It should be appreciated, however, that the embodiments provide many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The embodiments discussed are merely illustrative of specific ways to make and use the embodiments, and do not limit the scope of the embodiments.

The embodiments will be described with respect to embodiments in a specific context, namely an interconnect structure formed after passivation using a process similar to a dual damascene process. The embodiments may also be applied, however, to other interconnect structures.

With reference now to FIG. 1, there is shown a portion of a semiconductor die 100 including a semiconductor substrate 101 with metallization layers 103, a contact pad 105, a first passivation layer 107, and a second passivation layer 109. The semiconductor substrate 101 may comprise bulk silicon, doped or undoped, or an active layer of a silicon-on-insulator (SOI) substrate. Generally, an SOI substrate comprises a layer of a semiconductor material such as silicon, germanium, silicon germanium, SOI, silicon germanium on insulator (SGOI), or combinations thereof. Other substrates that may be used include multi-layered substrates, gradient substrates, or hybrid orientation substrates.

Active devices (not shown) may be formed on the semiconductor substrate 101. As one of ordinary skill in the art will recognize, a wide variety of active devices such as capacitors, resistors, inductors and the like may be used to generate the desired structural and functional requirements of the design for the semiconductor die 100. The active devices may be formed using any suitable methods either within or else on the surface of the semiconductor substrate 101.

The metallization layers 103 are formed over the semiconductor substrate 101 and the active devices and are designed to connect the various active devices to form functional circuitry. While illustrated in FIG. 1 as a single layer, the metallization layers 103 may be formed of alternating layers of dielectric (e.g., low-k dielectric material) and conductive material (e.g., copper) and may be formed through any suitable process (such as deposition, damascene, dual damascene, etc.). In an embodiment there may be four layers of metallization separated from the semiconductor substrate 101 by at least one interlayer dielectric layer (ILD), but the precise number of metallization layers 103 is dependent upon the design of the semiconductor die 100.

The contact pad 105 may be formed over and in electrical contact with the metallization layers 103. The contact pad 105 may comprise aluminum, but other materials, such as copper, may alternatively be used. The contact pad 105 may be formed using a deposition process, such as sputtering, to form a layer of material (not shown) and portions of the layer of material may then be removed through a suitable process (such as photolithographic masking and etching) to form the contact pad 105. However, any other suitable process may be utilized to form the contact pad 105. The contact pad 105 may be formed to have a thickness of between about 0.5  $\mu\text{m}$  and about 4  $\mu\text{m}$ , such as about 1.45  $\mu\text{m}$ .

The first passivation layer 107 may be formed on the semiconductor substrate 101 over the metallization layers 103 and the contact pad 105. The first passivation layer 107 may be made of one or more suitable dielectric materials such as silicon oxide, silicon nitride, low-k dielectrics such as carbon doped oxides, extremely low-k dielectrics such as porous carbon doped silicon dioxide, combinations of these, or the like. The first passivation layer 107 may be formed through a process such as chemical vapor deposition (CVD), although any suitable process may be utilized, and may have a thickness between about 0.5  $\mu\text{m}$  and about 5  $\mu\text{m}$ , such as about 9.25  $\text{\AA}$ .

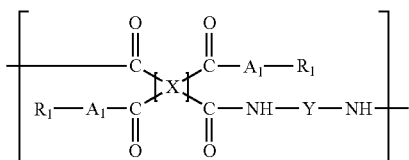
After the first passivation layer 107 has been formed, an opening may be made through the first passivation layer 107 by removing portions of the first passivation layer 107 to expose at least a portion of the underlying contact pad 105. The opening allows for contact between the contact pad 105

3

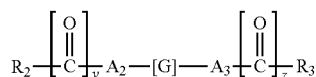
and a PPI **803** (not illustrated in FIG. **1** but illustrated and discussed further below with respect to FIG. **8**). The opening may be formed using a suitable photolithographic mask and etching process, although any suitable process to expose portions of the contact pad **105** may be used.

The second passivation layer **109** may be formed over the first passivation layer **107** and in the opening to contact the contact pad **105**. In an embodiment the second passivation layer **109** may comprise, for example, a negative tone photosensitive composition such as a negative tone photosensitive polyimide composition. For example, such a negative tone photosensitive polyimide composition in the second passivation layer **109** may comprise a negative tone photosensitive polyimide resin along with a photoactive components (PACs) placed into a negative tone photosensitive polyimide solvent.

In an embodiment the negative tone photosensitive polyimide resin may comprise a polymer that is made up of monomers of the following formula:



where X is a tetravalent organic group derived from alicyclic tetracarboxylic acid dianhydrides having 3 to 30 carbon atoms; A<sub>1</sub> is an oxygen atom or an NH group; and Y is a di-valent organic group derived from aliphatic, alicyclic, or non-conjugated aromatic diamines with carbon atoms between 3 and 30, wherein side chains have one or more ethylenically unsaturated, cross-linkable bonds. R<sub>1</sub> is a hydrogen atom or an organic group having 1 to 20 carbon atoms including one or more ethylenically unsaturated bonds or, alternatively, is a group comprising a photopolymerizable olefin double bond. In a particular embodiment R<sub>1</sub> may comprise the following structure:



where R<sub>2</sub> is an aryl residue such as C<sub>2</sub>H<sub>3</sub> or C<sub>3</sub>H<sub>5</sub>, R<sub>3</sub> is a residue with at least one photopolymerizable olefin double bond, G is a divalent aliphatic or aromatic group, which may be unsubstituted or has one or more hydroxyl substituents, A<sub>2</sub> is an oxygen atom or an NR group, in which R indicates a hydrogen atom or a C<sub>1</sub>-C<sub>4</sub> alkyl group, A<sub>3</sub> is an oxygen atom or an NR group, in which R indicates a hydrogen atom or a C<sub>1</sub>-C<sub>4</sub> alkyl group, y is 0 or 1 and z is 0 or 1.

Additionally, while the negative tone photosensitive polyimide resin may be one of the embodiments as described above, the negative tone photosensitive polyimide resin is not intended to be limited to only the specific examples described herein. Rather, any suitable negative tone photosensitive polyimide resin may alternatively be utilized, and all such photosensitive polyimide resins are fully intended to be included within the scope of the embodiments.

The PACs may be photoactive components such as photoacid generators, photobase generators, free-radical generators, or the like, and the PACs may be positive-acting or negative-acting. In an embodiment in which the PACs are a photoacid generator, the PACs may comprise halogenated

4

triazines, onium salts, diazonium salts, aromatic diazonium salts, phosphonium salts, sulfonium salts, iodonium salts, imide sulfonate, oxime sulfonate, disulfone, o-nitrobenzyl sulfonate, sulfonated esters, halogenerated sulfonyloxy dicarboximides, diazodisulfones, α-cyanoxyamine-sulfonates, imidesulfonates, ketodiazosulfones, sulfonyldiaz-oesters, 1,2-di(arylsulfonyl)hydrazines, nitrobenzyl esters, and the s-triazine derivatives, suitable combinations of these, and the like.

Specific examples of photoacid generators that may be used include α-(trifluoromethylsulfonyloxy)-bicyclo[2.2.1]hept-5-ene-2,3-dicarboximide (MDT), N-hydroxy-naphthalimide (DDSN), benzoin tosylate, t-butylphenyl-α-(p-toluenesulfonyloxy)-acetate and t-butyl-α-(p-toluenesulfonyloxy)-acetate, triarylsulfonium and diaryliodonium hexafluoroantimonates, hexafluoroarsenates, trifluoromethanesulfonates, iodonium perfluorooctanesulfonate, N-camphorsulfonyloxynaphthalimide, N-pentafluorophenylsulfonyloxynaphthalimide, ionic iodonium sulfonates such as diaryl iodonium (alkyl or aryl) sulfonate and bis-(di-t-butylphenyl)iodonium camphanylsulfonate, perfluoroalkanesulfonates such as perfluoropentanesulfonate, perfluorooctanesulfonate, perfluoromethanesulfonate, aryl (e.g., phenyl or benzyl) triflates such as triphenylsulfonium triflate or bis-(t-butylphenyl)iodonium triflate; pyrogallol derivatives (e.g., trimesylate of pyrogallol), trifluoromethanesulfonate esters of hydroxyimides, α,α-bis-sulfonyl-diazomethanes, sulfonate esters of nitro-substituted benzyl alcohols, naphthoquinone-4-diazides, alkyl disulfones, and the like.

In an embodiment in which the PACs are a free-radical generator, the PACs may comprise n-phenylglycine, aromatic ketones such as benzophenone, N,N'-tetramethyl-4,4'-diaminobenzophenone, N,N'-tetraethyl-4,4'-diaminobenzophenone, 4-methoxy-4'-dimethylaminobenzo-phenone, 3,3'-dimethyl-4-methoxybenzophenone, p,p'-bis(dimethylamino)benzo-phenone, p,p'-bis(diethylamino)-benzophenone, anthraquinone, 2-ethylantraquinone, naphthaquinone and phenanthraquinone, benzoin such as benzoin, benzoinmethylether, benzoinethylether, benzoinisopropylether, benzoin-n-butylether, benzoin-phenylether, methylbenzoin and ethylbenzoin, benzyl derivatives such as dibenzyl, benzyldiphenyldisulfide and benzyldimethylketal, acridine derivatives such as 9-phenylacridine and 1,7-bis(9-acridinyl)heptane, thioxanthenes such as 2-chloro-thioxanthone, 2-methylthioxanthone, 2,4-diethylthioxanthone, 2,4-dimethylthioxanthone and 2-isopropylthioxanthone, acetophenones such as 1,1-dichloroacetophenone, p-t-butylldichloro-acetophenone, 2,2-diethoxyacetophenone, 2,2-dimethoxy-2-phenylacetophenone, and 2,2-dichloro-4-phenoxyacetophenone, 2,4,5-triarylimidazole dimers such as 2-(o-chlorophenyl)-4,5-diphenylimidazole dimer, 2-(o-chlorophenyl)-4,5-di-(m-methoxyphenyl)imidazole dimer, 2-(o-fluorophenyl)-4,5-diphenylimidazole dimer, 2-(o-methoxyphenyl)-4,5-diphenylimidazole dimer, 2-(p-methoxyphenyl)-4,5-diphenylimidazole dimer, 2,4-di-(p-methoxyphenyl)-5-phenylimidazole dimer, 2-(2,4-dimethoxyphenyl)-4,5-diphenylimidazole dimer and 2-(p-methylmercaptophenyl)-4,5-diphenylimidazole dimer, suitable combinations of these, or the like.

In an embodiment in which the PACs are a photobase generator, the PACs may comprise quaternary ammonium dithiocarbamates, α aminoketones, oxime-urethane containing molecules such as dibenzophenoneoxime hexamethylene diurethan, ammonium tetraorganylborate salts, and N-(2-nitrobenzyloxycarbonyl) cyclic amines, suitable combinations of these, or the like. However, as one of ordinary skill in the art

will recognize, the chemical compounds listed herein are merely intended as illustrated examples of the PACs and are not intended to limit the embodiments to only those PACs specifically described. Rather, any suitable PAC may alternatively be utilized, and all such PACs are fully intended to be included within the scope of the present embodiments.

In an embodiment the negative tone photosensitive polyimide solvent may be an organic solvent, and may comprise any suitable solvent such as ketones, alcohols, polyalcohols, ethers, glycol ethers, cyclic ethers, aromatic hydrocarbons, esters, propionates, lactates, lactic esters, alkylene glycol monoalkyl ethers, alkyl lactates, alkyl alkoxypropionates, cyclic lactones, monoketone compounds that contain a ring, alkylene carbonates, alkyl alkoxyacetate, alkyl pyruvates, ethylene glycol alkyl ether acetates, diethylene glycols, propylene glycol alkyl ether acetates, alkylene glycol alkyl ether esters, alkylene glycol monoalkyl esters, or the like.

Specific examples of materials that may be used as the negative tone photosensitive polyimide solvent for the negative tone photosensitive polyimide composition include acetone, methanol, ethanol, toluene, xylene, 4-hydroxy-4-methyl-2-pentanone, tetrahydrofuran, methyl ethyl ketone, cyclohexanone, methyl isoamyl ketone, 2-heptanone, ethylene glycol, ethylene glycol monoacetate, ethylene glycol dimethyl ether, ethylene glycol methylethyl ether, ethylene glycol monoethyl ether, methyl cellosolve acetate, ethyl cellosolve acetate, diethylene glycol, diethylene glycol monoacetate, diethylene glycol monomethyl ether, diethylene glycol diethyl ether, diethylene glycol dimethyl ether, diethylene glycol ethylmethyl ether, diethylene glycol monoethyl ether, diethylene glycol monobutyl ether, ethyl 2-hydroxypropionate, methyl 2-hydroxy-2-methylpropionate, ethyl 2-hydroxy-2-methylpropionate, ethyl ethoxyacetate, ethyl hydroxyacetate, methyl 2-hydroxy-2-methylbutanate, methyl 3-methoxypropionate, ethyl 3-methoxypropionate, methyl 3-ethoxypropionate, ethyl 3-ethoxypropionate, ethyl acetate, butyl acetate, methyl lactate and ethyl lactate, propylene glycol, propylene glycol monoacetate, propylene glycol monoethyl ether acetate, propylene glycol monomethyl ether acetate, propylene glycol monopropyl methyl ether acetate, propylene glycol monobutyl ether acetate, propylene glycol monobutyl ether acetate, propylene glycol monomethyl ether propionate, propylene glycol monoethyl ether propionate, propylene glycol methyl ether acetate, propylene glycol ethyl ether acetate, ethylene glycol monomethyl ether acetate, ethylene glycol monoethyl ether acetate, propylene glycol monomethyl ether, propylene glycol monoethyl ether, propylene glycol monopropyl ether, propylene glycol monobutyl ether, ethylene glycol monomethyl ether, ethylene glycol monoethyl ether, propyl lactate, and butyl lactate, ethyl 3-ethoxypropionate, methyl 3-methoxypropionate, methyl 3-ethoxypropionate, and ethyl 3-methoxypropionate,  $\beta$ -propiolactone,  $\beta$ -butyrolactone,  $\gamma$ -butyrolactone,  $\alpha$ -methyl- $\gamma$ -butyrolactone,  $\beta$ -methyl- $\gamma$ -butyrolactone,  $\gamma$ -valerolactone,  $\gamma$ -caprolactone,  $\gamma$ -octanoic lactone,  $\alpha$ -hydroxy- $\gamma$ -butyrolactone, 2-butanone, 3-methylbutanone, pinacolone, 2-pentanone, 3-pentanone, 4-methyl-2-pentanone, 2-methyl-3-pentanone, 4,4-dimethyl-2-pentanone, 2,4-dimethyl-3-pentanone, 2,2,4,4-tetramethyl-3-pentanone, 2-hexanone, 3-hexanone, 5-methyl-3-hexanone, 2-heptanone, 3-heptanone, 4-heptanone, 2-methyl-3-heptanone, 5-methyl-3-heptanone, 2,6-dimethyl-4-heptanone, 2-octanone, 3-octanone, 2-nonanone, 3-nonanone, 5-nonanone, 2-decanone, 3-decanone, 4-decanone, 5-hexene-2-one, 3-pentene-2-one, cyclopentanone, 2-methylcyclopentanone, 3-methylcyclopentanone, 2,2-dimethylcyclopentanone, 2,4,4-trimethylcyclopentanone, cyclohexanone, 3-methylcyclohexanone,

4-methylcyclohexanone, 4-ethylcyclohexanone, 2,2-dimethylcyclohexanone, 2,6-dimethylcyclohexanone, 2,2,6-trimethylcyclohexanone, cycloheptanone, 2-methylcycloheptanone, 3-methylcycloheptanone, pyrene carbonate, vinylene carbonate, ethylene carbonate, and butylene carbonate, acetate-2-methoxyethyl, acetate-2-ethoxyethyl, acetate-2-(2-ethoxyethoxy)ethyl, acetate-3-methoxy-3-methylbutyl, acetate-1-methoxy-2-propyl, dipropylene glycol, monomethylether, monoethylether, monopropylether, monobutylether, monophenylether, dipropylene glycol monoacetate, dioxane, ethyl lactate, methyl acetate, ethyl acetate, butyl acetate, methyl pyruvate, ethyl pyruvate, propyl pyruvate, methyl methoxypropionate, ethyl ethoxypropionate, n-methylpyrrolidone (NMP), 2-methoxyethyl ether (diglyme), ethylene glycol monomethyl ether, propylene glycol monomethyl ether; methyl propanoate, ethyl propanoate and ethyl ethoxy propanoate, methylethyl ketone, cyclohexanone, 2-heptanone, carbon dioxide, cyclopentanone, cyclohexanone, ethyl 3-ethoxypropionate, propylene glycol methyl ether acetate (PGMEA), methylene cellosolve, butyle acetate, and 2-ethoxyethanol, N-methylformamide, N,N-dimethylformamide, N-methylformanilide, N-methylacetamide, N,N-dimethylacetamide, N-methylpyrrolidone, dimethylsulfoxide, benzyl ethyl ether, dihexyl ether, acetonylacetone, isophorone, caproic acid, caprylic acid, 1-octanol, 1-nonanol, benzyl alcohol, benzyl acetate, ethyl benzoate, diethyl oxalate, diethyl maleate,  $\gamma$ -butyrolactone, ethylene carbonate, propylene carbonate, phenyl cellosolve acetate, or the like.

In an embodiment the negative tone photosensitive polyimide resin and the PACs, along with any desired additives or other agents, are added to the negative tone photosensitive polyimide solvent for application. For example, the negative tone photosensitive polyimide resin may have a concentration of between about 5% and about 50%, such as about 25%, while the PACs may have a concentration of between about 0.1% and about 20%, such as about 5%. Once added, the mixture is then mixed in order to achieve an even composition throughout the negative tone photosensitive polyimide composition in order to ensure that there are no defects caused by an uneven mixing or non-constant composition. Once mixed together, the negative tone photosensitive polyimide composition may either be stored prior to its usage or else used immediately.

Once ready, the second passivation layer **109** may be utilized by initially applying the negative tone photosensitive polyimide composition onto the first passivation layer **107**. The second passivation layer **109** may be applied to the first passivation layer **107** so that the second passivation layer **109** coats an upper exposed surface of the first passivation layer **107**, and may be applied using a process such as a spin-on coating process, a dip coating method, an air-knife coating method, a curtain coating method, a wire-bar coating method, a gravure coating method, a lamination method, an extrusion coating method, combinations of these, or the like. The second passivation layer **109** may be placed to a thickness of between about 1  $\mu$ m to about 40  $\mu$ m.

FIGS. 2A-2B illustrate a patterning and development of the second passivation layer **109**. Once applied, the second passivation layer **109** may be exposed to form an exposed region **201** and an unexposed region **203** within the second passivation layer **109**. In an embodiment the exposure may be initiated by placing the substrate **101** and the second passivation layer **109** into an imaging device **200** for exposure. The imaging device **200** may comprise a support plate **204**, a energy source **207**, a patterned mask **209** between the support plate **204** and the energy source **207**, and optics **213**. In an embodi-

ment the support plate **204** is a surface to which the semiconductor device **100** and the second passivation layer **109** may be placed or attached to and which provides support and control to the substrate **101** during exposure of the second passivation layer **109**. Additionally, the support plate **204** may be movable along one or more axes, as well as providing any desired heating or cooling to the substrate **101** and second passivation layer **109** in order to prevent temperature gradients from affecting the exposure process.

In an embodiment the energy source **207** supplies energy **211** such as light to the second passivation layer **109** in order to induce a reaction of the PACs, which in turn reacts with, e.g., the negative tone photosensitive polyimide resin to chemically alter those portions of the second passivation layer **109** to which the energy **211** impinges. In an embodiment the energy **211** may be electromagnetic radiation, such as g-rays (with a wavelength of about 436 nm), i-rays (with a wavelength of about 365 nm), ultraviolet radiation, far ultraviolet radiation, x-rays, electron beams, or the like. The energy source **207** may be a source of the electromagnetic radiation, and may be a KrF excimer laser light (with a wavelength of 248 nm), an ArF excimer laser light (with a wavelength of 193 nm), a F<sub>2</sub> excimer laser light (with a wavelength of 157 nm), or the like, although any other suitable source of energy **211**, such as mercury vapor lamps, xenon lamps, carbon arc lamps or the like, may alternatively be utilized.

The patterned mask **209** is located between the energy source **207** and the second passivation layer **109** in order to block portions of the energy **211** to form a patterned energy **215** prior to the energy **211** actually impinging upon the second passivation layer **109**. In an embodiment the patterned mask **209** may comprise a series of layers (e.g., substrate, absorbance layers, anti-reflective coating layers, shielding layers, etc.) to reflect, absorb, or otherwise block portions of the energy **211** from reaching those portions of the second passivation layer **109** which are not desired to be illuminated. The desired pattern may be formed in the patterned mask **209** by forming openings through the patterned mask **209** in the desired shape of illumination.

Optics (represented in FIG. 2A by the trapezoid labeled **213**) may be used to concentrate, expand, reflect, or otherwise control the energy **211** as it leaves the energy source **207**, is patterned by the patterned mask **209**, and is directed towards the second passivation layer **109**. In an embodiment the optics **213** comprise one or more lenses, mirrors, filters, combinations of these, or the like to control the energy **211** along its path. Additionally, while the optics **213** are illustrated in FIG. 2A as being between the patterned mask **209** and the second passivation layer **109**, elements of the optics **213** (e.g., individual lenses, mirrors, etc.) may also be located at any location between the energy source **207** (where the energy **211** is generated) and the second passivation layer **109**.

In an embodiment the semiconductor device **100** with the second passivation layer **109** is placed on the support plate **204**. Once the pattern has been aligned to the semiconductor device **100**, the energy source **207** generates the desired energy **211** (e.g., light) which passes through the patterned mask **209** and the optics **213** on its way to the second passivation layer **109**. The patterned energy **215** impinging upon portions of the second passivation layer **109** induces a reaction of the PACs within the second passivation layer **109**. The chemical reaction products of the PACs' absorption of the patterned energy **215** (e.g., acids/bases/free radicals) then reacts, chemically altering the second passivation layer **109** in those portions that were illuminated through the patterned mask **209**.

Optionally, the exposure of the second passivation layer **109** may occur using an immersion lithography technique. In such a technique an immersion medium (not individually illustrated in FIG. 2A) may be placed between the imaging device **200** (and particularly between a final lens of the optics **213**) and the second passivation layer **109**. With this immersion medium in place, the second passivation layer **109** may be patterned with the patterned energy **215** passing through the immersion medium.

In this embodiment a protective layer (also not individually illustrated in FIG. 2A) may be formed over the second passivation layer **109** in order to prevent the immersion medium from coming into direct contact with the second passivation layer **109** and leaching or otherwise adversely affecting the second passivation layer **109**. In an embodiment the protective layer is insoluble within the immersion medium such that the immersion medium will not dissolve it and is immiscible in the second passivation layer **109** such that the protective layer will not adversely affect the second passivation layer **109**. Additionally, the protective layer is transparent so that the patterned energy **215** may pass through the protective layer without hindrance.

In an embodiment the protective layer comprises a protective layer resin within a protective layer solvent. The material used for the protective layer solvent is, at least in part, dependent upon the components chosen for the second passivation layer **109**, as the protective layer solvent should not dissolve the materials of the second passivation layer **109** so as to avoid degradation of the second passivation layer **109** during application and use of the protective layer. In an embodiment the protective layer solvent includes alcohol solvents, fluorinated solvents, and hydrocarbon solvents.

Specific examples of materials that may be utilized for the protective layer solvent include methanol, ethanol, 1-propanol, isopropanol, n-propanol, 1-butanol, 2-butanol, 2-methyl-2-propanol, 3-methyl-1-butanol, isobutyl alcohol, tert-butyl alcohol, 1-pentanol, 2-pentanol, 3-pentanol, n-hexanol, cyclohexanol, 1-hexanol, 1-heptanol, 1-octanol, 2-hexanol, 2-heptanol, 2-octanol, 3-hexanol, 3-heptanol, 3-octanol, 4-octanol, 2-methyl-2-butanol, 3-methyl-1-butanol, 3-methyl-2-butanol, 2-methyl-1-butanol, 2-methyl-1-pentanol, 2-methyl-2-pentanol, 2-methyl-3-pentanol, 3-methyl-1-pentanol, 3-methyl-2-pentanol, 3-methyl-3-pentanol, 4-methyl-1-pentanol, 4-methyl-2-pentanol, 2,2,3,3,4,4-hexafluoro-1-butanol, 2,2,3,3,4,4,5,5-octafluoro-1-pentanol, 2,2,3,3,4,4,5,5,6,6-decafluoro-1-hexanol, 2,2,3,3,4,4-hexafluoro-1,5-pentanediol, 2,2,3,3,4,4,5,5-octafluoro-1,6-hexanediol, 2,2,3,3,4,4,5,5,6,6,7,7-dodecafluoro-1,8-diol, 2-fluoroanisole, 2,3-difluoroanisole, perfluorohexane, perfluoroheptane, perfluoro-2-pentanone, perfluoro-2-butyltetrahydrofuran, perfluorotetrahydrofuran, perfluorotributylamine, perfluorotetrabutylamine, toluene, xylene and anisole, and aliphatic hydrocarbon solvents, such as n-heptane, n-nonane, n-octane, n-decane, 2-methylheptane, 3-methylheptane, 3,3-dimethylhexane, 2,3,4-trimethylpentane, combinations of these, or the like.

The protective layer resin may comprise a protective layer repeating unit. In an embodiment the protective layer repeating unit may be an acrylic resin with a repeating hydrocarbon structure having a carboxyl group, an alicyclic structure, an alkyl group having one to five carbon atoms, a phenol group, or a fluorine atom-containing group. Specific examples of the alicyclic structure include a cyclohexyl group, an adamantyl group, a norbornyl group, a isobornyl group, a tricyclodecyl group, a tetracyclododecyl group, and the like. Specific examples of the alkyl group include an n-butyl group, an

isobutyl group, or the like. However, any suitable protective layer resin may alternatively be utilized.

The protective layer composition may also include additional additives to assist in such things as adhesion, surface leveling, coating, and the like. For example, the protective layer composition may further comprise a protective layer surfactant, although other additives may also be added, and all such additions are fully intended to be included within the scope of the embodiment. In an embodiment the protective layer surfactant may be an alkyl cationic surfactant, an amide-type quaternary cationic surfactant, an ester-type quaternary cationic surfactant, an amine oxide surfactant, a betaine surfactant, an alkoxyate surfactant, a fatty acid ester surfactant, an amide surfactant, an alcohol surfactant, an ethylenediamine surfactant, or a fluorine- and/or silicon-containing surfactant.

Specific examples of materials that may be used for the protective layer surfactant include polyoxyethylene alkyl ethers, such as polyoxyethylene lauryl ether, polyoxyethylene stearyl ether, polyoxyethylene cetyl ether and polyoxyethylene oleyl ether; polyoxyethylene alkyl aryl ethers, such as polyoxyethylene octyl phenol ether and polyoxyethylene nonyl phenol ether; polyoxyethylene-polyoxypropylene block copolymers; sorbitan fatty acid esters, such as sorbitan monolaurate, sorbitan monopalmitate, sorbitan monostearate, sorbitan monooleate, sorbitan trioleate and sorbitan tristearate; and polyoxyethylene sorbitan monolaurate, polyoxyethylene sorbitan monopalmitate, polyoxyethylene sorbitan monostearate, polyoxyethylene sorbitan trioleate and polyoxyethylene sorbitan tristearate.

Prior to application of the protective layer onto the second passivation layer 109, the protective layer resin and desired additives are first added to the protective layer solvent to form a protective layer composition. The protective layer solvent is then mixed to ensure that the protective layer composition has a consistent concentration throughout the protective layer composition.

Once the protective layer composition is ready for application, the protective layer composition may be applied over the second passivation layer 109. In an embodiment the application may be performed using a process such as a spin-on coating process, a dip coating method, an air-knife coating method, a curtain coating method, a wire-bar coating method, a gravure coating method, a lamination method, an extrusion coating method, combinations of these, or the like. In an embodiment the second passivation layer 109 may be applied such that it has a thickness over the surface of the second passivation layer 109 of about 100 nm.

After the protective layer composition has been applied to the second passivation layer 109, a protective layer pre-bake may be performed in order to remove the protective layer solvent. In an embodiment the protective layer pre-bake may be performed at a temperature suitable to evaporate the protective layer solvent, such as between about 40° C. and 150° C., although the precise temperature depends upon the materials chosen for the protective layer composition. The protective layer pre-bake is performed for a time sufficient to cure and dry the protective layer composition, such as between about 10 seconds to about 5 minutes, such as about 90 seconds.

Once the protective layer has been placed over the second passivation layer 109, the semiconductor device 100 with the second passivation layer 109 and the protective layer are placed on the support plate 204, and the immersion medium may be placed between the protective layer and the optics 213. In an embodiment the immersion medium is a liquid having a refractive index greater than that of the surrounding

atmosphere, such as having a refractive index greater than 1. Examples of the immersion medium may include water, oil, glycerine, glycerol, cycloalkanol, or the like, although any suitable medium may alternatively be utilized.

The placement of the immersion medium between the protective layer and the optics 213 may be done using, e.g., an air knife method, whereby fresh immersion medium is applied to a region between the protective layer and the optics 213 and controlled using pressurized gas directed towards the protective layer to form a barrier and keep the immersion medium from spreading. In this embodiment the immersion medium may be applied, used, and removed from the protective layer for recycling so that there is fresh immersion medium used for the actual imaging process.

However, the air knife method described above is not the only method by which the second passivation layer 109 may be exposed using an immersion method. Any other suitable method for imaging the second passivation layer 109 using an immersion medium, such as immersing the entire substrate 101 along with the second passivation layer 109 and the protective layer, using solid barriers instead of gaseous barriers, or using an immersion medium without a protective layer, may also be utilized. Any suitable method for exposing the second passivation layer 109 through the immersion medium may be used, and all such methods are fully intended to be included within the scope of the embodiments.

FIG. 2B illustrates a development of the second passivation layer 109 with the use of a developer after the second passivation layer 109 has been exposed. After the second passivation layer 109 has been exposed, the second passivation layer 109 may be developed using a first developer. In an embodiment in which the second passivation layer 109 is the negative tone photosensitive polyimide, the first developer may be a basic aqueous solution to remove those portions of the second passivation layer 109 which were unexposed to the patterned energy 215. Such basic aqueous solutions may include tetramethyl ammonium hydroxide (TMAH), tetra butyl ammonium hydroxide, sodium hydroxide, potassium hydroxide, sodium carbonate, sodium bicarbonate, sodium silicate, sodium metasilicate, aqueous ammonia, monomethylamine, dimethylamine, trimethylamine, monoethylamine, diethylamine, triethylamine, monoisopropylamine, diisopropylamine, triisopropylamine, monobutylamine, dibutylamine, monoethanolamine, diethanolamine, triethanolamine, dimethylaminoethanol, diethylaminoethanol, potassium metasilicate, sodium carbonate, tetraethylammonium hydroxide, combinations of these, or the like.

In an embodiment in which immersion lithography is utilized to expose the second passivation layer 109 and a protective layer is utilized to protect the second passivation layer 109 from the immersion medium, the developer may be chosen to remove not only those portions of the second passivation layer 109 that are desired to be removed, but may also be chosen to remove the protective layer in the same development step. Alternatively, the protective layer may be removed in a separate process, such as by a separate solvent from the developer or even an etching process to remove the protective layer from the second passivation layer 109 prior to development.

The first developer may be applied to the second passivation layer 109 using, e.g., a spin-on process. In this process the first developer is applied to the second passivation layer 109 from above the second passivation layer 109 while the semiconductor device 100 (and the second passivation layer 109) is rotated. In an embodiment the first developer may be at a temperature of between about 10° C. and about 80° C.,

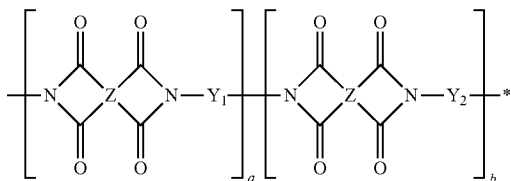
11

such as about 50° C., and the development may continue for between about 1 minute to about 60 minutes, such as about 30 minutes.

However, while the spin-on method described herein is one suitable method for developing the second passivation layer 109 after exposure, it is intended to be illustrative and is not intended to limit the embodiments. Rather, any suitable method for development, including dip processes, puddle processes, spray-on processes, combinations of these, or the like, may alternatively be used. All such development processes are fully intended to be included within the scope of the embodiments.

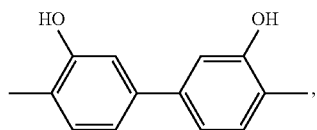
FIG. 2B illustrates a cross-section of the development process in an embodiment in which the first developer is used to remove the unexposed regions of the second passivation layer 109. The developer is applied to the second passivation layer 109 and dissolves the unexposed portion 205 of the second passivation layer 109. This dissolving and removing of the unexposed portion 205 of the second passivation layer 109 leaves behind a first opening 217 within the second passivation layer 109 that patterns the second passivation layer 109 in the shape of the patterned energy 215, thereby transferring the pattern of the patterned mask 209 to the second passivation layer 109. In an embodiment the first opening 217 may have a width of between about 2 μm to about 300 μm, such as about 5 μm to about 300 μm, and may be any desired shape such as round, oval, or polygonal.

FIG. 3 illustrates the placement of a third passivation layer 301 over the second passivation layer 109. In an embodiment the third passivation layer 301 may be a positive tone composition such as a positive tone photosensitive polyimide composition (instead of the negative tone photosensitive polyimide composition described above with respect to the second passivation layer 109). For example, the positive tone photosensitive polyimide composition may comprise a positive tone photosensitive polyimide resin along with the PACs within a positive tone photosensitive polyimide solvent. In an embodiment the positive tone photosensitive polyimide resin may be a polymer with a repeating unit represented by the following formula:



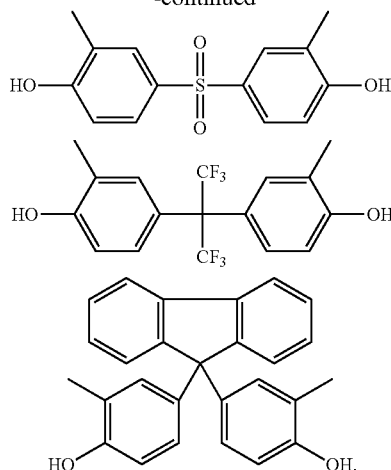
where Z is a tetravalent organic group derived from one or more tetracarboxylic acids, including 3,4-dicarboxy-1,2,3,4-tetrahydro-6-tert-butyl-1-naphthalene succinic dianhydride (DTBDA), or derivatives thereof, a is from 1 to 150, b is from 1 to 400, Y<sub>1</sub> is a divalent organic group derived from a diamine, Y<sub>2</sub> is a divalent aliphatic group or aromatic organic group derived from a diamine.

Specific examples of Y<sub>1</sub> include the following formulas:



12

-continued



Specific examples of Y<sub>2</sub> include aromatic diamines, such as p-phenylenediamine, m-phenylenediamine, 2,4,6-trimethyl-1,3-phenylenediamine, 2,3,5,6-tetramethyl-1,4-phenylenediamine, 4,4'-diaminodiphenyl ether, 3,4'-diaminodiphenyl ether, 3,3'-diaminodiphenyl ether, 4,4'-diaminodiphenyl sulfide, 4,4'-diaminodiphenylmethane, 3,4'-diaminodiphenylmethane, 3,3'-diaminodiphenylmethane, 4,4'-methylene-bis(2-methylaniline), 4,4'-methylene-bis(2,6-dimethylaniline), 4,4'-methylene-bis(2,6-diethylaniline), 4,4'-methylene-bis(2-isopropyl-6-methylaniline), 4,4'-methylene-bis(2,6-diisopropylaniline), 4,4'-diaminodiphenylsulfone, 3,3'-diaminodiphenylsulfone, benzidine, o-tolidine, m-tolidine, 3,3',5,5'-tetramethylbenzidine, 2,2'-bis(trifluoromethyl)benzidine, 1,4-bis(4-aminophenoxy)benzene, 1,3-bis(4-aminophenoxy)benzene, 1,3-bis(3-aminophenoxy)benzene, bis[4-(4-aminophenoxy)phenyl]sulfone, bis[4-(3-aminophenoxy)phenyl]sulfone, 2,2-bis[4-(4-aminophenoxy)phenyl]propane, and 2,2-bis[4-(3-aminophenoxy)phenyl]propane; aliphatic diamines, such as 1,6-hexanediamine, 1,4-cyclohexanediamine, 1,3-cyclohexanediamine, 1,4-bis(aminomethyl)cyclohexane, 1,3-bis(aminomethyl)cyclohexane, 4,4'-diaminodicyclohexylmethane, 4,4'-diaminobenzanilide, 2,2-bis[4-(4-aminophenoxy)phenyl]hexafluoropropane, 1,3-bis(3-aminophenoxy)phenyl]tetramethyldisiloxane, bis(p-aminophenoxy)dimethylsilane, diaminoethane, diaminododecane, 1,3-bis(4-aminophenoxy)benzene, 2,2-bis[4-(4-aminophenoxy)phenyl]propane, 1,1-bis(4-aminophenoxyphenyl)cyclohexane, bis[4-(4-aminophenoxy)phenyl]sulfone, 1,3-bis(3-aminophenoxy)benzene, 5-amino-1,3,3-trimethylcyclohexanemethylamine, 4,4'-bis(4-aminophenoxy)biphenyl, 1,1-bis(4-aminophenyl)cyclohexane, .alpha.,.alpha.'-bis(4-aminophenyl)-1,4-diisopropylbenzene, 1,3-bis(4-aminophenoxy)-2,2-dimethylpropane, 1,3-bis(4-aminophenoxy)benzene, 9,9-bis(4-aminophenyl)fluorine, and 4,4'-diamino-3,3'-dimethyldicyclohexylmethane, combinations of these, or the like.

In an embodiment the positive tone photosensitive polyimide solvent may be an organic solvent, and may comprise any suitable solvent such as ketones, alcohols, polyalcohols, ethers, glycol ethers, cyclic ethers, aromatic hydrocarbons, esters, propionates, lactates, lactic esters, alkylene glycol monoalkyl ethers, alkyl lactates, alkyl alkoxypropionates, cyclic lactones, monoketone compounds that contain a ring, alkylene carbonates, alkyl alkoxyacetate, alkyl pyruvates, ethylene glycol alkyl ether acetates, diethylene glycols, pro-



## 13

pylene glycol alkyl ether acetates, alkylene glycol alkyl ether esters, alkylene glycol monoalkyl esters, or the like.

Specific examples of materials that may be used as the positive tone photosensitive polyimide solvent for the positive tone photosensitive polyimide composition include acetone, methanol, ethanol, toluene, xylene, 4-hydroxy-4-methyl-2-pentanone, tetrahydrofuran, methyl ethyl ketone, cyclohexanone, methyl isoamyl ketone, 2-heptanone, ethylene glycol, ethylene glycol monoacetate, ethylene glycol dimethyl ether, ethylene glycol methylethyl ether, ethylene glycol monoethyl ether, methyl cellulose acetate, ethyl cellosolve acetate, diethylene glycol, diethylene glycol monoacetate, diethylene glycol monomethyl ether, diethylene glycol diethyl ether, diethylene glycol dimethyl ether, diethylene glycol ethylmethyl ether, diethylene glycol monoethyl ether, diethylene glycol monobutyl ether, ethyl 2-hydroxypropionate, methyl 2-hydroxy-2-methylpropionate, ethyl 2-hydroxy-2-methylpropionate, ethyl ethoxyacetate, ethyl hydroxyacetate, methyl 2-hydroxy-2-methylbutanate, methyl 3-methoxypropionate, ethyl 3-methoxypropionate, methyl 3-ethoxypropionate, ethyl 3-ethoxypropionate, ethyl acetate, butyl acetate, methyl lactate and ethyl lactate, propylene glycol, propylene glycol monoacetate, propylene glycol monoethyl ether acetate, propylene glycol monomethyl ether acetate, propylene glycol monopropyl methyl ether acetate, propylene glycol monobutyl ether acetate, propylene glycol monobutyl ether acetate, propylene glycol monomethyl ether propionate, propylene glycol monoethyl ether propionate, propylene glycol methyl ether acetate, propylene glycol ethyl ether acetate, ethylene glycol monomethyl ether acetate, ethylene glycol monoethyl ether acetate, propylene glycol monomethyl ether, propylene glycol monoethyl ether, propylene glycol monopropyl ether, propylene glycol monobutyl ether, ethylene glycol monomethyl ether, ethylene glycol monoethyl ether, propyl lactate, and butyl lactate, ethyl 3-ethoxypropionate, methyl 3-methoxypropionate, methyl 3-ethoxypropionate, and ethyl 3-methoxypropionate,  $\beta$ -propiolactone,  $\beta$ -butyrolactone,  $\gamma$ -butyrolactone,  $\alpha$ -methyl- $\gamma$ -butyrolactone,  $\beta$ -methyl- $\gamma$ -butyrolactone,  $\gamma$ -valerolactone,  $\gamma$ -caprolactone,  $\gamma$ -octanoic lactone,  $\alpha$ -hydroxy- $\gamma$ -butyrolactone, 2-butanone, 3-methylbutanone, pinacolone, 2-pentanone, 3-pentanone, 4-methyl-2-pentanone, 2-methyl-3-pentanone, 4,4-dimethyl-2-pentanone, 2,4-dimethyl-3-pentanone, 2,2,4,4-tetramethyl-3-pentanone, 2-hexanone, 3-hexanone, 5-methyl-3-hexanone, 2-heptanone, 3-heptanone, 4-heptanone, 2-methyl-3-heptanone, 5-methyl-3-heptanone, 2,6-dimethyl-4-heptanone, 2-octanone, 3-octanone, 2-nonanone, 3-nonanone, 5-nonanone, 2-decanone, 3-decanone, 4-decanone, 5-hexene-2-one, 3-pentene-2-one, cyclopentanone, 2-methylcyclopentanone, 3-methylcyclopentanone, 2,2-dimethylcyclopentanone, 2,4,4-trimethylcyclopentanone, cyclohexanone, 3-methylcyclohexanone, 4-methylcyclohexanone, 4-ethylcyclohexanone, 2,2-dimethylcyclohexanone, 2,6-dimethylcyclohexanone, 2,2,6-trimethylcyclohexanone, cycloheptanone, 2-methylcycloheptanone, 3-methylcycloheptanone, pyrene carbonate, vinylene carbonate, ethylene carbonate, and butylene carbonate, acetate-2-methoxyethyl, acetate-2-ethoxyethyl, acetate-2-(2-ethoxyethoxy)ethyl, acetate-3-methoxy-3-methylbutyl, acetate-1-methoxy-2-propyl, dipropylene glycol, monomethylether, monoethylether, monopropylether, monobutylether, monophenylether, dipropylene glycol monoacetate, dioxane, ethyl lactate, methyl acetate, ethyl acetate, butyl acetate, methyl pyruvate, ethyl pyruvate, propyl pyruvate, methyl methoxypropionate, ethyl ethoxypropionate, n-methylpyrrolidone (NMP), 2-methoxyethyl ether (diglyme), ethylene glycol monomethyl ether, propylene glycol monomethyl ether; methyl propionate, ethyl propionate and ethyl ethoxy propionate, methylethyl ketone, cyclohexanone, 2-heptanone, carbon dioxide, cyclopentanone, cyclohexanone, ethyl 3-ethoxypropionate, propylene glycol methyl ether acetate (PGMEA), methylene cellosolve, butyle acetate, and 2-ethoxyethanol, N-methylformamide, N,N-dimethylformamide, N-methylformanilide, N-methylacetamide, N,N-dimethylacetamide, N-methylpyrrolidone, dimethylsulfoxide, benzyl ethyl ether, dihexyl ether, acetonylacetone, isophorone, caproic acid, caprylic acid, 1-octanol, 1-nonanol, benzyl alcohol, benzyl acetate, ethyl benzoate, diethyl oxalate, diethyl maleate,  $\gamma$ -butyrolactone, ethylene carbonate, propylene carbonate, phenyl cellosolve acetate, or the like.

## 14

In an embodiment the positive tone photosensitive polyimide resin is placed into the positive tone photosensitive polyimide solvent along with the PACs and mixed to form the positive tone photosensitive polyimide composition. For example, the positive tone photosensitive polyimide resin may have a concentration of between about 5% and about 50%, such as about 25%, while the PACs may have a concentration of between about 0.1% and about 20%, such as about 5%. Once the positive tone photosensitive polyimide composition has been mixed to have a constant composition throughout the mixture, the positive tone photosensitive polyimide composition is applied to the second passivation layer 109 to a thickness of between about 1  $\mu$ m to about 40  $\mu$ m. The application may be performed using, e.g. a spin-coating method, although any suitable method may alternatively be utilized.

FIG. 4 illustrates the patterning and development of the third passivation layer 301. In an embodiment the third passivation layer 301 may be patterned in order to form a second opening 401 and third openings 403. The second opening 401 may be formed over and connected to the first opening 217 in the second passivation layer 109 in order to expose a portion of the contact pad 105. The third openings 403 may be formed to define the dimensions of routing for conductive lines to be formed within the third passivation layer 301.

To pattern the third passivation layer 301, the substrate 101 along with the third passivation layer 301 may be placed into the imaging device 200 (described above with respect to FIG. 2A) or a different imaging device (not illustrated), and the third passivation layer 301 may be exposed to the patterned energy source 215 to define regions within the third passivation layer 301 for the second opening 401 and the third openings 403. In an embodiment the second opening 401 and the third openings 403 may have a width of between about 2  $\mu$ m and about 300  $\mu$ m, such as about 5  $\mu$ m to about 300  $\mu$ m. Additionally, the second opening 401 and the third openings 403 may be any desired shape, such as round, oval, polygonal, or the like.

Once exposed, the third passivation layer 301 may be developed using a second developer. In an embodiment the second developer may be a basic aqueous solution to remove those portions of the second passivation layer 109 which were exposed to the patterned energy 215 and which have had their solubility modified and changed through the chemical reactions. Such basic aqueous solutions may include tetra methyl ammonium hydroxide (TMAH), tetra butyl ammonium hydroxide, sodium hydroxide, potassium hydroxide, sodium carbonate, sodium bicarbonate, sodium silicate, sodium metasilicate, aqueous ammonia, monomethylamine, dimethylamine, trimethylamine, monoethylamine, diethylamine, triethylamine, monoisopropylamine, diisopropylamine, triisopropylamine, monobutylamine, dibutylamine, monoethanolamine, diethanolamine, triethanolamine, dimethylamino-

15

ethanol, diethylaminoethanol, potassium metasilicate, sodium carbonate, tetraethylammonium hydroxide, combinations of these, or the like.

The second developer may be applied to the third passivation layer **301** using, e.g., a spin-on process. In this process the second developer is applied to the third passivation layer **301** from above the third passivation layer **301** while the semiconductor device **100** (and the third passivation layer **301**) is rotated. In an embodiment the second developer may be at a temperature of between about 10° C. and about 80° C., such as about 50° C., and the development may continue for between about 1 minute to about 60 minutes, such as about 30 minutes.

FIG. 5 illustrates that, once the third passivation layer **301** has been patterned and developed, the third passivation layer **301** and the second passivation layer **109** may be cured (represented in FIG. 5 by the wavy lines labeled **501**). In an embodiment the curing process **501** may be performed by placing the substrate **101** along with the second passivation layer **109** and the third passivation layer **301** onto, e.g., a hot plate or other type of heating apparatus, wherein the temperature of the second passivation layer **109** and the third passivation layer **301** may be increased. In an embodiment the curing process may be performed at a temperature of 150° C. to about 400° C. for a time of between about 1 hour to about 2 hours.

Additionally, after the curing process, a descum process may be utilized in order to remove undesired residue or particles that may remain on the contact pad **105**, the second passivation layer **109**, and the third passivation layer **301** after the patterning, developments, and curing process. In an embodiment the descum process comprises exposing the contact pad **105**, the second passivation layer **109**, and the third passivation layer **301** to a plasma environment, such as an oxygen plasma environment, in order to react and remove any undesired residue. In a particular embodiment the descum process may be a reactive ion etch process.

FIG. 6 illustrates a formation of a seed layer **601**. Once the second passivation layer **109** and the third passivation layer **301** have been formed, the seed layer **601** may be formed within the first opening **217**, the second opening **401**, and the third openings **403**. In an embodiment the seed layer **601** may be, e.g., a titanium copper alloy, although any suitable material, such as copper, may alternatively be utilized. The seed layer **601** may be formed through a suitable formation process such as CVD or sputtering.

FIG. 7 illustrates a formation of conductive material **701** on the seed layer **601**, filling and overfilling the first opening **217**, the second opening **401**, and the third openings **403**. In an embodiment the conductive material **701** may comprise copper, although other suitable materials, such as AlCu or Au, may alternatively be utilized. The conductive material **701** may be formed through a deposition process such as electroplating or electroless plating, although other methods may such as CVD or PVD may alternatively be utilized.

FIG. 8 illustrates a planarization process such as a chemical mechanical polishing (CMP) process that may be used to remove excess amounts of the conductive material **701** from those regions outside of the first opening **217**, the second opening **401**, and the third openings **403** and form the PPI **803**. In an embodiment in which the planarization process is a CMP, a combination of etching materials and abrading materials are put into contact with the conductive material **701** and a grinding pad **801** is used to grind away the conductive material **701** until the conductive material **701** is planarized with the third passivation layer **301**.

16

After planarization, the PPI **803** and the third passivation layer **301** may be cleaned in order to remove any undesired residue that may have remained after the planarization process. In an embodiment the PPI **803** and the third passivation layer **301** may be cleaned by rinsing the PPI **803** and the passivation layer **301** with deionized water. Alternatively, a Standard Clean-1 (SC-1) or a Standard Clean-2 (SC-2) cleaning process may be used. All such cleaning processes are fully intended to be included within the scope of the embodiments.

Once the PPI **803** and the third passivation layer **301** have been cleaned, the PPI **803** and the passivation layer **301** may be baked. In an embodiment the PPI **803** and the third passivation layer **301** may be baked by placing the substrate **101** along with the PPI **803** and the passivation layer **301** into a furnace or other heating device (e.g., a hot plate) and increasing the temperature of the third passivation layer **301** and the PPI **803** to a temperature of between about 150° C. and about 450° C., such as about 200° C. The PPI **803** and the third passivation layer **301** may be baked for a time of between about 5 min and about 240 min, such as about 60 min.

By forming the PPI **803** as described herein, issues surrounding the formation of the PPI **803** may be reduced or eliminated. In particular, by using these embodiments, an undercut issue between a seed layer and an overlying electroplated layer that is usually present for fine pitches (e.g., less than about 5 μm) may be avoided, while also lowering costs and avoiding any loss of critical dimensions. Additionally, the seed layer **601** in these embodiments is also located along the sidewalls of the PPI **803**, and there is no depth bias associated with these embodiments. Finally, as the PPI **803** in these embodiments have a corner round profile, there is no crown issue as with some other processes.

FIG. 9 illustrates a placement of an external contact **901** along with a the placement of a buffer layer **903**. In an embodiment the external contact **901** may comprise a material such as tin, or other suitable materials, such as silver, lead-free tin, or copper. In an embodiment in which the external contact **901** is a tin solder bump, the external contact **901** may be formed by initially forming a layer of tin through such commonly used methods such as evaporation, electroplating, printing, solder transfer, ball placement, etc., to a thickness of, e.g., about 100 μm. Once a layer of tin has been formed on the structure, a reflow may be performed in order to shape the material into the desired bump shape.

Once the external contact **901** has been placed and reflowed, the buffer layer **903** may be placed or formed on the third passivation layer **301** in order to protect and buffer the underlying structures. In an embodiment the buffer layer **902** is a dielectric passivation material such as silicon dioxide, polyimide, or the like, that may be placed or formed, depending at least in part on the precise material chosen, using a process such as chemical vapor deposition, physical vapor deposition, spin-coating, or the like. The buffer layer **902** may be formed to a thickness of between about 5 μm and about 200 μm, such as about 100 μm.

In accordance with an embodiment, a semiconductor device comprising a patterned positive tone photosensitive material over a substrate is provided. The patterned positive tone photosensitive material comprises openings. A seed layer is along the openings and a conductive material is adjacent to the seed layer.

In accordance with another embodiment, a semiconductor device comprising a patterned negative tone photosensitive polyimide layer over a substrate is provided. A patterned positive tone photosensitive polyimide layer is over and in contact with the patterned negative tone photosensitive poly-

17

imide layer, the patterned positive tone photosensitive polyimide layer comprising at least one opening.

In accordance with yet another embodiment, a method of manufacturing a semiconductor device comprising placing a first photosensitive material over a conductive region over a substrate is provided. The first photosensitive material is patterned to remove unexposed first photosensitive material and expose the conductive region. A second photosensitive material is placed over the first photosensitive material. The second photosensitive material is patterned to remove exposed second photosensitive material and expose the conductive region, the patterning the second photosensitive material forming a patterned second photosensitive material and at least one opening in the patterned second photosensitive material. A seed layer is formed along sidewalls of the at least one opening.

Although the present embodiments and their advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the embodiments as defined by the appended claims. For example, the precise shape of the first opening, the second opening, and the third openings may be changed, or the precise methods of formation may be altered. Additionally, any suitable number of masks for the die, such as two masks, three masks, four masks, or any other suitable number of masks, may be utilized.

Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the embodiments, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the embodiments. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

What is claimed is:

1. A method of manufacturing a semiconductor device, the method comprising:

placing a first photosensitive material over a conductive region over a substrate;

patterning the first photosensitive material to remove unexposed first photosensitive material and expose the conductive region;

placing a second photosensitive material over the first photosensitive material;

patterning the second photosensitive material to remove exposed second photosensitive material and expose the conductive region, the patterning the second photosensitive material forming a patterned second photosensitive material and at least one opening in the patterned second photosensitive material, wherein the first photosensitive material extends from a first sidewall of the at least one opening to a second sidewall of the at least one opening; and

forming a seed layer along sidewalls of the at least one opening.

2. The method of claim 1, wherein the first photosensitive material is a negative tone photosensitive polyimide.

3. The method of claim 2, wherein the second photosensitive material is a positive tone photosensitive polyimide.

18

4. The method of claim 3, wherein the patterning the first photosensitive material further comprises:

exposing the first photosensitive material to a patterned energy source; and

developing the first photosensitive material after the exposing the first photosensitive material.

5. The method of claim 4, wherein the developing the first photosensitive material further comprises applying a first alkaline developer.

6. The method of claim 4, wherein the patterning the second photosensitive material further comprises:

exposing the second photosensitive material to a patterned energy source; and

developing the second photosensitive material after the exposing the first photosensitive material.

7. The method of claim 6, wherein the developing the second photosensitive material further comprises applying a second alkaline developer.

8. The method of claim 1, further comprising:

plating a conductive material onto the seed layer; and planarizing the conductive material with the patterned second photosensitive material.

9. A method of manufacturing a semiconductor device, the method comprising:

applying a negative tone photosensitive material to a substrate;

patterning the negative tone photosensitive material to form a patterned negative tone photosensitive material with first openings extending through the patterned negative tone photosensitive material;

applying a positive tone photosensitive material over the patterned negative tone photosensitive material;

patterning the positive tone photosensitive material to form a patterned positive tone photosensitive material with second openings through the patterned positive tone photosensitive material, wherein the patterned negative tone photosensitive material extends from a first sidewall of a first one of the second openings to a second sidewall of the first one of the second openings;

depositing a seed layer extending along sidewalls of the second openings; and

forming a conductive material adjacent to the seed layer.

10. The method of claim 9, wherein the applying the negative tone photosensitive material applies a negative tone photosensitive polyimide.

11. The method of claim 10, wherein the applying the positive tone photosensitive material applies a positive tone photosensitive polyimide.

12. The method of claim 9, wherein the forming the conductive material further comprises forming a post-passivation interconnect.

13. The method of claim 12, wherein the forming the post-passivation interconnect further comprises:

forming a contact region; and

forming routing lines laterally separated from the contact region.

14. The method of claim 13, wherein the post-passivation interconnect has a pitch of less than about 5  $\mu\text{m}$ .

15. A method of manufacturing a semiconductor device, the method comprising:

forming a first opening in a negative tone photosensitive polyimide over a substrate to form a patterned negative tone photosensitive polyimide;

applying a positive tone photosensitive polyimide in physical contact with the patterned negative tone photosensitive polyimide; and

19

forming a second opening and a third opening through the positive tone photosensitive polyimide, wherein the second opening is directly over the first opening and the third opening extends through but not beyond the positive tone photosensitive polyimide.

5

**16.** The method of claim **15**, further comprising filling the first opening, the second opening, and the third opening with a conductive material.

**17.** The method of claim **16**, wherein the filling the first opening, the second opening, and the third opening further comprises:

10

depositing a seed layer along sidewalls of the first opening, the second opening, and the third opening; and electroplating a conductive material onto the seed layer.

**18.** The method of claim **17**, wherein the conductive material is copper.

15

**19.** The method of claim **16**, wherein the filling the first opening, the second opening, and the third opening further comprises forming a post-passivation interconnect.

**20.** The method of claim **19**, further comprising curing the negative tone photosensitive polyimide and the positive tone photosensitive polyimide after the forming the second opening and the third opening.

20

\* \* \* \* \*

20